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ON THE
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CAUSES

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EARTHQUAKES.

Which were read before the ROYAL SOCIETY, APRIL 5, 1750.

By STEPHEN HALES, D.D, F.R.S. *R.*

LONDON:

Printed for R. MANBY and H. S. Cox, on Ludgate-Hill. 1750.

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CAUSES

OF

Jos. Banks

Which were read before the ROYAL SOCIETY
CITY, April 1780.

BY STEPHEN HALE, D.D.

LONDON:

Printed for R. Mansel and H. S. Carr, on the
2nd-1780.

SOME
CONSIDERATIONS
ON THE
Causes of Earthquakes.

AS the late Earthquakes in *London*, and some other Parts of *England*, have roused the Attention of Mankind to consider the Causes of them, both in a religious and natural View: And as in a religious View they have been considered by the Bishop of *London* in his excellent Letter to the Clergy and People of *London* and *Westminster*, which has been received with general Approbation: So I shall here give a short Account of what seems to me a probable natural Cause of them.

But I must first obviate an Objection of some serious well-meaning People, who are
apt

apt to be offended at any Attempts to give a natural Account of Earthquakes, which but rarely happening in these more northern Parts of the World, are apt to be looked upon as the more Miraculous. But it ought to be considered, that the ordinary Course of Nature is as much carried on by the Divine Agency, as the extraordinary and miraculous Events. God sometimes changes the Order of Nature, with design to chastise Man for his Disobedience and Follies, natural Evils being graciously designed by him as moral Goods. All Events are under his Direction and fulfill his Will. On the other Hand, there are some who make light of Earthquakes, because they are capable of being accounted for by natural Causes. But the Hand of God is not to be overlooked in these Things, under whose Government all natural Agents act, especially such rare and unusual Events as Earthquakes; God uses all Creatures to be the Instruments of his Will, natural and moral Agents are all under his Direction. When he inflicts a Famine on a Nation, it is not the less the Hand

Hand of God, because we know the natural Causes of it, viz. great Drought and unkindly Seasons. *Fire and Hail, Snow and Vapours, and stormy Wind fulfill his Word*, Psal. cxlviii. 8. Infectious Air, pestilential Diseases, and Earthquakes, however occasioned by natural Causes, are under the Divine Influence.—He not only orders and directs the Operations of Nature; but also influences the Actions of moral Agents, turning as he pleases, the Hearts of the Governors of the Nations, so as frequently to chastise Mankind, by that severe Scourge, and great Disgrace of human Nature, *War*.
 Earthquakes are not therefore to be slightly regarded, because we think we can give a probable natural Account of them, neither ought we on that Account to encourage ourselves to go carelessly on in wicked Courses. If national Judgments do not overtake us, yet it cannot be long before we shall come into the severer Punishments of our future State. *And tho' Sentence against an evil Work is not speedily executed, tho' a Sinner do evil an hundred Times, and his Days be prolonged;*

prolonged; yet surely I know it shall not be well with the wicked, Eccles. viii. 11, 12, 13

It may not be improper, on this Occasion, to mention another constant and uninterrupted Plague, in which, of late Years, we have been and are like to continue Sufferers, in common with many other Nations. A Plague of all others, the greatest that ever befel unhappy Man; it being by far the most destructive, not only of the Lives, but also of the Morals of Mankind, both a natural and a moral Evil. I mean fermented distilled Spirituous Liquors, of all Denominations: Did God Almighty destroy as many by Earthquakes, as are yearly destroyed by distilled Spirituous Liquors, which is probably about a Million of Persons in a Year, all over the World; how great a Terror and Consternation would it cause every where! But alas! with what Unconcernedness, with what Calmness and even Complacency, is this enormous both natural and moral Evil received and even fostered among us? Inasmuch, that it is now by
a just

a just Judgment, become the Curse and the Punishment of the World, even the greatest that ever beset Mankind. Notwithstanding which this enchanting Syren so bewitches and infatuates the Nations, that it spreads its baleful Influence far and wide, making yearly farther and farther Devastations, both of the Lives and Morals of Mankind, and even debasing the Breed of Man.

As to the Affair of Earthquakes, particularly that which happened at *London, March 8, 1749-50.* about 20 Minutes before Six in the Morning, I being then awake in Bed on a ground Floor, near *St. Martin's in the Fields* Church in *London*, very sensibly felt the Bed heave, and consequently the Earth must heave too; there was an obscure rushing Noise in the House, which ended in a loud Explosion up in the Air like that of a small Cannon. The whole Duration from the Beginning of the Earthquake to the End was 3 or 4 Seconds of Time. The Soldiers who were upon Duty in *St James's Park*,

and others who were up, saw a blackish Cloud, with considerable Lightning, just before the Earthquake began; it was also very calm Weather.

And in the History of Earthquakes it is observed that they generally begin in calm Weather, with a black Cloud; and when the Air is clear just before an Earthquake, yet there is then often Signs of plenty of inflammable sulphureous Matter in the Air, such as *Ignes fatui*, or Jack-a-Lanterns, and the Meteors which are called falling Stars.

Now I have shewn many Years since, in the *Appendix* to my *Statistical Essays*, Experiment 3. page 280. the Effect that the Mixture of a pure and a sulphureous Air have on each other, *viz.* by turning the Mouth downwards into a Pail of Water, a Glass Vessel of a Capacity sufficient to hold about two Quarts, with a Neck about twenty Inches long, and two Inches wide; then by putting under it in a proper Glass Vessel with a long narrow Neck, a Mixture of

of *Aqua fortis*, and pounded *Pyrites*, viz. the Stone with which Vitriol is made; there will be a brisk Ferment, which will fill the Glas with reddish sulphureous Fumes, which by generating more Air than they destroy, will cause the Water with which the whole Neck of the Glas Vessel was filled, to subside considerably. When the reddish sulphureous Air in the upper Part is clear, by standing two or three Hours; if then, the Mouth of the inverted Glas is lifted out of the Water, so as to let the Water in the Neck of the Glas fall out; which supposing it to be a Pint, an equal Quantity of fresh Air will rush in at the Mouth of the Neck of the Vessel, which must immediately be immersed in the Water. And upon the Mixture of the fresh Air, with the then clear sulphureous Air, there will instantly arise a violent Agitation between the two Airs, and they will become from transparent and clear, a reddish turbid Fume of the Colour of those Vapours, which were seen several Evenings before the late Earthquakes. During which Effervescence a Quantity of

Air nearly equal to what fresh Air was let in, will be destroyed, which is evident by the rising up of the Water in the Neck of the Glass almost as high as before. And if after the Effervescence of the mixed Airs is over, and become clear again, fresh Air be admitted as before, they will again grow reddish and turbid, and destroy the new admitted Air as before ; and that after several repeated Admissions of Air. But after each Readmission of fresh Air, the Quantity destroyed will be less and less, till no more will be destroyed. And it is the same after standing several Weeks, provided in the mean Time too much fresh Air had not been admitted. Now I found the Sum total of the fresh Air thus destroyed to be nearly equal to the first Quantity of the sulphureous Air, in the inverted Glass.

Since we have in this Experiment, a full Proof of the brisk Agitation and Effervescence, which arises from the Mixture of fresh Air, with Air that is impregnated with sulphureous Vapours, which are raised from several
 mineral

mineral Substances, especially from the *Pyrites* which abound in the Earth, may we not with good Reason conclude, that the irksome Heat which we feel, in what is called a close sultry Temperature of Air, is occasioned by the intestine Motion, between the Air, and the sulphureous Vapours which are exhaled from the Earth? which Effervescence ceases as soon as these Vapours are equably and uniformly mixed with the Air, as happens also in the Effervescences and Ferments of other Liquors. The common Observation therefore, that Lightning cools the Air, seems to be founded on good Reason; that being the utmost and last Effort of this Effervescence.

May we not hence also with good Probability conclude, that the first kindling of Lightning is effected by the sudden Mixture of the pure serene Air above the Clouds, with the sulphureous Vapours which are sometimes raised in plenty, immediately below the Clouds; the most dreadful Thunders being usually when the Air is
very

very black with Clouds, it rarely thundering without Clouds? Clouds serving in this Case, like the above mentioned inverted Glass, as a Partition between the pure and sulphureous Airs, which must therefore upon their sudden Admixture, thro' the Interstices of the Clouds, make, like the two Airs in the Glass, a more violent Effervescence, than if those Airs had without the Intervention the Clouds more gradually intermixed, by the constant more gradual Ascent of the warmer sulphureous Vapours from the Earth, a Descent of the cold serene Air from above. And tho' there was no luminous Flash of Light in the Glass, yet when such sudden Effervescence arises, among a vast Quantity of such Vapours in the open Expanse of Air, it may, not improbably, acquire so rapid a Velocity, as to kindle the sulphureous Vapours, and thereby become luminous.

And since from the Effects that Lightning is observed to have on the Lungs of Animals, which it often kills, by destroying

ing the Air's Elasticity in them, as also from its bursting Windows outwards, by destroying the Air's Elasticity on the outside of those Windows. Since, I say, it is hence probable, that the sulphureous Fumes do destroy a great deal of elastick Air, it should therefore cause great Commotions and Concussions in the Air, when the Air rushes into those evacuated Places, which it must necessarily do with great Velocity. Dr. *Papin* has calculated the Velocity, with which Air rushes into an exhausted Receiver, when driven by the whole Pressure of the Atmosphere to be at the Rate of 1305 Feet in a Second of Time, which is at the Rate of 889 Miles in an Hour, which is near 18 Times a greater Velocity than that of the strongest Storms, which is estimated to be at the Rate of 50 Miles in an Hour *. 

Hence we see that an outrageous Hurricane may be caused by destroying a small Proportion of the Elasticity of the Air of any Place in respect to the Whole. No wonder

* *Lewthorp's* Abridgment, *Philos. Trans.* v. 1. p. 586.
then

then that such violent Commotions of the Air should produce Hurricanes, and Thunder-showers, especially in the warmer Climates, where both the sulphureous and watry Vapours, being raised much higher and in greater Plenty, cause more violent Effects.

Monfieur *de Buffon*, in his natural History and Theory of the Earth, mentions black dark Clouds in the Air, near the tempestuous *Cape of Good Hope*, and also in the Ocean off of *Guinea*, which are called by the Sailors the *Ox's Eye*, which are often the Fore-runners of terrible Storms and Hurricanes; whence it is to be suspected, that they are large Collections of sulphureous Vapours, which by destroying suddenly a great Quantity of the elastick Air, cause the ambient Air to rush with great Violence into that Vacuity, thereby producing Tempests and Hurricanes. And off the Coast of *Guinea* they have sometimes three or four of these Hurricanes in a Day, the Fore-runners of which, are these black sulphureous

phureous Clouds; with a serene clear Air and calm Sea, which on a sudden turns Tempestuous on the Explosion of these sulphureous Clouds. And at *Jamaica* they never had an Earthquake when there was a Wind to disperse the sulphureous Vapours.

In like manner we find in the late Earthquakes at *London*, and in the Accounts of many other Earthquakes; that before they happen there is usually a calm Air with a black sulphureous Cloud, which Cloud would probably be dispersed, like a Fog, were there a Wind; which Dispersion would prevent the Earthquake, which is probably caused by the explosive Lightning of this sulphureous Cloud; being both nearer the Earth than common Lightnings, and also at a Time when sulphureous Vapours are rising from the Earth, in greater Quantity than usual, which is often occasioned by a long Series of hot and dry Weather. In which combined Circumstances the ascending sulphureous Vapours in the Earth may probably take fire, and thereby cause an

Earth Lightning, which is first kindled at the Surface and not at great Depths, as has been thought, whole Exploſion is the immediate Cauſe of an Earthquake. *

I am ſenſible that it may ſeem improbable that the aſcending ſulphureous Vapours in the Earth ſhould thus be kindled; but ſince they are continually aſcending thro' the Pores of the Earth, more or leſs, for many good and uſeful Purpoſes, it is plain there is room for them to paſs; beſides, as *Monſ. de Buffon* ſays, Naturaliſts have obſerved perpendicular and oblique Cleſts in all kinds of Layers of Earth, not only among Rocks, but alſo in all Kinds of Earth, that have not been removed, as is obſervable wherever the Earth is opened to any Depth. Now theſe Cleſts are cauſed

* It is in the like Manner that thoſe Meteors which are called falling Stars, are ſuppoſed to kindle into a Flame at the upper Part of a ſulphureous Train, which is kindled downwards into a Flame, in the ſame Manner as a freſh blown out Candle is inſtantly lighted from another Candle held above it at a Diſtance, in the ſulphureous inflammable Smoke of it.

by

by the drying of the several horizontal Layers of Earth ; and will also be considerably the wider in long dry hot Seasons, which are usually the preparatory Forerunners of Earthquakes. And the Explosion of the sulphureous Vapours may probably widen them more.

It is very observable that even Volcano's, in the Opinion of *Borelli* and other Naturalists, began first to kindle near the Surface and Top of the Mountains, and not by the fermenting of the Pyrites and sulphureous Vapours in the Caverns, in the lower Parts of the Mountain. *Monf. de Buffon* says, that Earthquakes are most frequent where there are Volcano's, sulphureous Matter abounding most there ; but that tho' they continue burning long, yet they are not very extensive. But that the other sort of Earthquakes, which are not caused by a Volcano, extend often to a great Distance. These are much longer East and West, than broad North and South ; and shake a Zone of Earth with different Degrees of Force in

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different

different Parts of their Course, viz. in proportion to the different Quantities of explosive sulphureous Matter in different Places. These kind of Earthquakes are observed to be progressive, and take Time to extend to the great Distances, sometimes of some Thousands of Miles. They are an instantaneous Explosion in every Place, near the Surface of the Earth; and therefore do not produce Mountains and Islands near other Islands as Volcano's sometimes do.

The Earthquake in *London*, *March 8.* was thought to move from Eastward to Westward. *Monf. de Buffon* mentions an Earthquake at *Smyrna* in the Year 1688. which moved from West to East, and in the Earthquake at *London* on the eastern Side. And accordingly it was observable that the reddish Bows in the Air, which were seen several Days before that Earthquake, arose in the East, and proceeded Westward. It was observed after the Earthquake at *Smyrna*, that the Castle-walls, which run from East to West, were thrown
I
down

down, but those from North to South stood. And that the Houses on Rocks stood better than those on Earth *. It was observed that the Waters turned foul the Day before an Earthquake at *Boulogne* in *Italy*, which was probably occasioned by the Ascent of great Plenty of sulphureous Vapours thro' the Earth.

As to the hollow rumbling Noise which is usually heard in Earthquakes, it seems not improbable, that it may be occasioned, by the great Agitation, that the Electrical Æthereal Fluid is put into, by so great a Shock, of a large Mass of the Earth. For if the little Motion of a small revolving Glass

* *Monf. de Buffon* relates, that the Vibrations of the Earth in Earthquakes, have commonly been from North to South, as appears by the Motion of the Lamps in Churches; which makes it probable that tho' the Progress of the Earthquake at *Smyrna* was from West to East, yet the Vibrations of the Earth might be from North to South, and thereby occasion the falling of the Castle-walls which run from East to West; but not those which run from North to South. A probable Argument that as the freest Passage, so the greatest Explosions were made in the Clefts of the Earth, which run East and West, which would make the Vibrations North and South.

Globe,

Globe, can excite it to the Velocity of Lightning, and that with a Force sufficient to kill Animals : How much greater Agitation may it probably be excited to, by the explosive Force of an Earthquake ? The Explosion of a Cannon in St. James's Park, is observed to electrify the Glass of the Windows of the *Treasury*. And what makes it still more probable, is, the Analogy that there is between them in other respects : For as the electrical Flash rushes with the Velocity of Lightning, along the most solid Bodies, as Iron, &c. and as I have seen it run only on the irregular gilding of Leather, so, such solid Bodies are observed to be the Conductors of Aereal Lightning, which rends Oaks in Pieces, and has been known to run along, and melt an Iron Bell Wyre in two Sides of a Room, &c. And accordingly it was observed in the great Earthquake in *Jamaica*, that the most tremendous roaring was in the rocky Mountains. And in the late Earthquake of *March 8*, in *London*, the lowest Explosions were thought to be heard, near such large Stone Buildings,

Buildings, as Churches, with lofty Steeples and Spires. I who lay in *Duke's Court* near *St. Martin's Church*, and was awake all the Time of the Earthquake, plainly heard a loud Exploſion up in the Air, like that of a ſmall Cannon, which made me conjecture that the Noiſe was owing to the ruſhing off, and ſudden Expanſion of the electrical Fluid at the Top of *St. Martin's Spire*; where all the electrical Effluvia which aſcended up along the larger Body of the Tower, being by Attraction ſtrongly condensed, and accelerated at the Point of the Spire, as they ruſhed off made ſo much the louder expanſive Exploſion.

F I N I S.

Boiling, as Churches, with lofty Spires
 and Spire. I who lay in Duke's Court near
 St. Martin's Church, and was awake all the
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 a small Cannon, which made me conjecture
 that the Noise was owing to the rubbing off
 and sudden Expansion of the electrical
 Fluid at the Top of St. Martin's Spire;
 where all the electrical Effluvia which ac-
 cumulated up along the larger Body of the
 Tower, being by Attraction strongly con-
 centred, and accumulated at the Point of the
 Spire, as is represented in the figure, the
 sudden expansion Explosion